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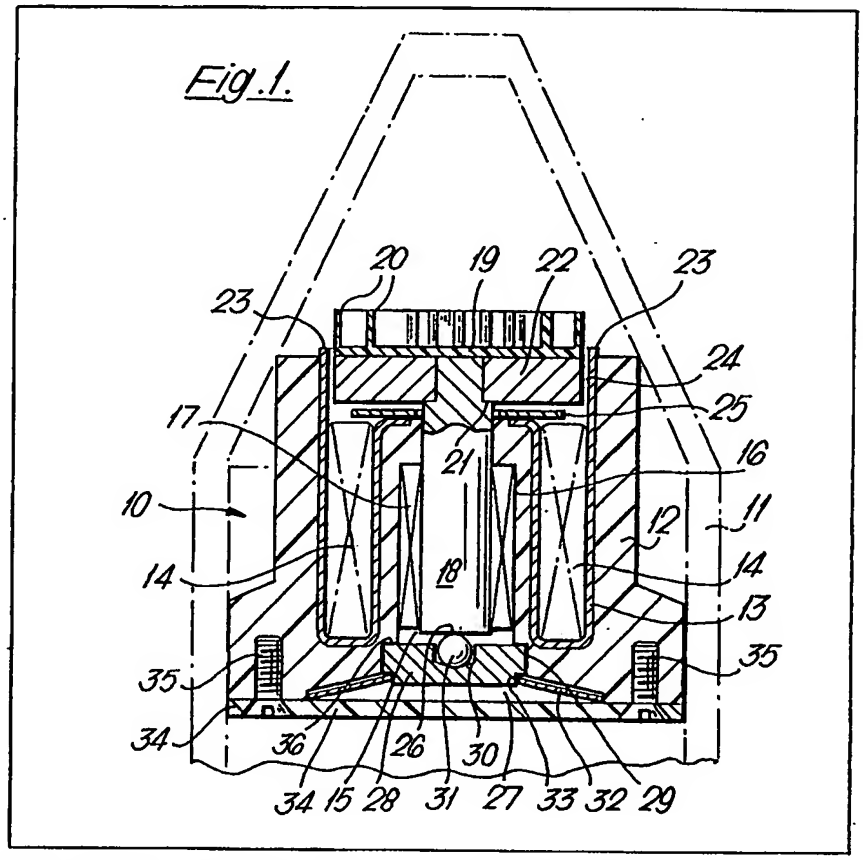
(54) **Air turbine generators for missiles**

(57) An air turbine generator 10 for a missile which is driven in motion by ram air hitting a turbine impeller 19 is made to a simple and inexpensive design by moulding a stator coil 14 and iron yoke 13 in a body 12 of thermoplastic or thermosetting resin formed with an axial passage 15 which has widened portions 16 and 33. The widened portion 16 contains a race of needle roller bearings to provide a journal bearing for a shaft 18 extending along the passage. The shaft carries the turbine impeller 19 and a permanent magnet rotor 22 having a plurality of poles to align with pole pieces of the iron yoke. A thrust bearing for the shaft consists of a ball 31 bearing against the end of the shaft and held to a thrust plate 28 biased by a compression washer 32. The ball makes point contact with the shaft to reduce friction and resilience of the washer relieves axial forces on the impeller while taking up little axial space.

Fig.1.



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The drawing originally filed was informal and the print here reproduced is taken from a later filed formal copy.

Fig.1.

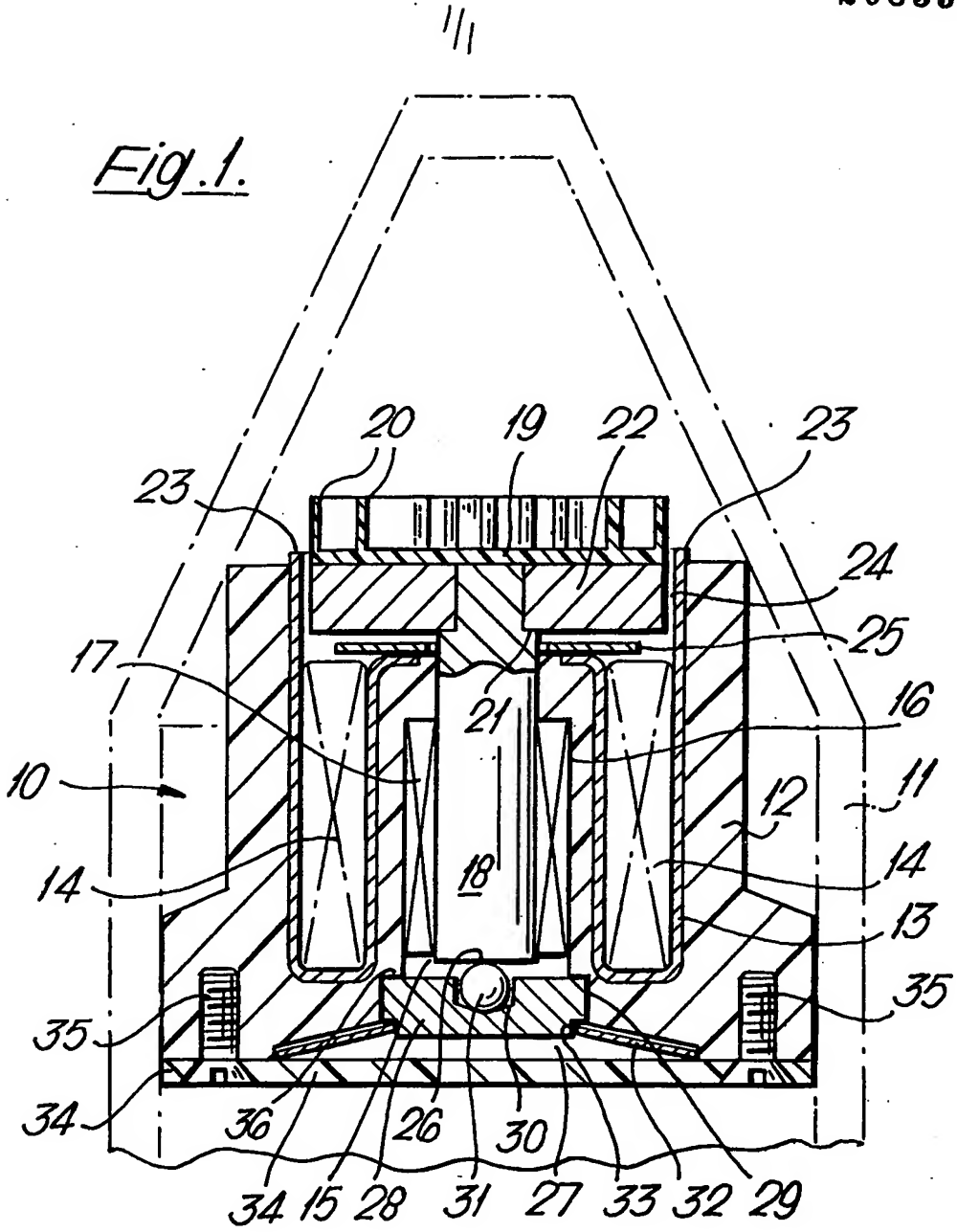
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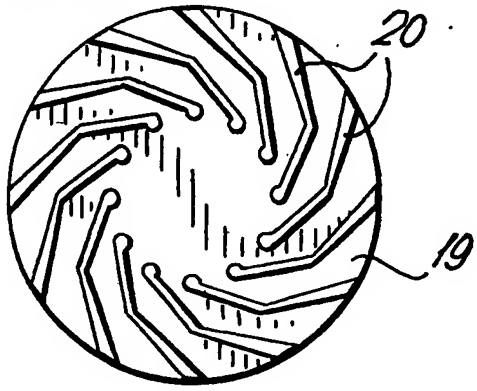
Fig.2.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SPECIFICATION
Air turbine generator

This invention relates to air turbine generators for missiles and in particular to bearing arrangements for the shafts thereof.

Air turbine generators are known for use in missiles and British Patent No. 1,388,533 describes a generator and the conditions under which such generators operate. A feature of the conditions is that the turbine is subject to a large and varying axial force due both to the ram effect of air against the turbine and to the effect of the inertia of the rotor assembly (that is, turbine, generator rotor and shaft) upon set-back.

In the aforementioned patent specification the aim of the invention is to prolong substantially the operating time of the generator and to this end the rotor assembly is supported at separate locations by ball races for axial and radial support and the invention is concerned with the provision of a flow path for air along a passage in the shaft and by way of the bearings to lubricate and cool them. Such cooling in combination with the ball race bearings leads to prolonged operation. Axial movement of the shaft relative to the bearings is accommodated by a pair of dished compression washers which limit the movement and accommodate normal air pressures on the turbine but allow the shaft to engage the stator body on set-back to prevent rotation until the bearing air flow is set up.

While the arrangement described above chooses a construction to satisfy the aim the construction itself leads to an inherently expensive device. A relatively sophisticated missile making use of the sort of flight time envisaged for the generator will itself be expensive and the cost justified but for a projectile, such as an artillery shell, wherein the time of flight is of the order of less than two minutes, the cost of the projectile is lower and the requirements for an air turbine generator used therewith are that it should be inexpensive to construct but operate reliably for the time of flight.

It is an object of the present invention to provide a turbine generator for a missile which satisfies the above requirements.

According to the present invention a generator for a missile comprises a stator body supporting an electromagnetic stator coil and a ferromagnetic yoke contained in a stator body, said coil being wound around an axial passage through the body, a shaft of non-magnetic material extending along the passage and journalled for part of its length within the passage by journal bearing means supporting the shaft against radial movement relative to the body, said shaft carrying a permanent magnet rotor and having one end adapted to carry an impeller arranged to face the direction of travel of a missile to which the generator is fitted to receive ram air directed axially of the shaft and to redirect it to cause rotation of the shaft and having the other end formed substantially flat in a plane perpendicular to the longitudinal axis of the shaft, and an axial thrust bearing comprising a thrust plate, adapted to close the portion of the axial passage containing the journal bearing and the shaft, and a ball bearing supported in a recess in the plate so as to bear against said other end of the shaft by resilient means held between the thrust plate and an end cover attached to the stator body, said resilient means reacting deformably to axial forces on the shaft transmitted by the ball and thrust plate.

An embodiment of the invention will now be described by way of example with reference to the accompanying drawings, in which:—

Figure 1 shows a sectional elevation through a missile turbine generator, and

Figure 2 is a plan view of the turbine impeller showing the disposition of blades.

Referring to the Figure 1, the missile turbine generator shown generally at 10 is dimensioned to fit into the nose cone of a missile, such as an artillery shell or like projectile, the outline of which is indicated by broken lines 11.

The generator comprises a stator body 12 formed of a thermoplastic or thermosetting resin moulded about a soft iron yoke 13 and electromagnetic coil 14.

The coil is wound on the yoke about a longitudinal axis of the body along which axis is formed a passage 15 extending through the moulding.

The axial passage 15 is enlarged to a first degree at 16 to accommodate a needle roller bearing 17 which is a press fit in the passage. The passage 15 contains a generator shaft 18 which is journalled along a major part of its length by the needle bearings 17.

The shaft carries at one end thereof an impeller 19 of moulded plastic material forming a circular disc in the plane perpendicular to the longitudinal axis of the shaft from the surface of which disc projects an array of blades 20 disposed as shown in Figure 2.

Also moulded on the shaft 15 and held by the impeller against a shoulder 21 on the shaft is a permanent magnet rotor 22.

The rotor 22 comprises an annular ring of sintered or cast aluminium-nickel-iron alloy such as ALNICO (trade mark) material magnetised so as to have poles of the same type at opposite portions of the ring and spaced at right-angles from opposite poles. The iron yoke 13 has projections 23 extending from the core of the coil parallel to the shaft 18 and folded around the outside of the coil to be spaced from opposite peripheral sides of the ring by an air gap 24.

The iron yoke members extends through the other end of the coil to a central portion surrounding the shaft and carries an annular member 25 having a pair of projecting lugs (not shown) also extending parallel to the longitudinal axis of the shaft 18 and spaced by the air gap 24 from the opposite peripheral sides of the ring but in a plane at right angles to the projections 23.

Each pole of the magnetic rotor thus

corresponds to a projection of the yoke.

The shaft 18 is supported as described above in the passage 15 for rotation and against radial forces by needle bearings 17. The end 26 of the shaft opposite to that carrying the impeller is made substantially flat in a plane perpendicular to its longitudinal axis and is supported by an axial thrust bearing arrangement 27.

The axial thrust bearing arrangement 27 comprises a circular thrust plate 28 formed of an aluminium alloy contained as a sliding fit in a portion 29 of the passage 15 enlarged to a greater degree than the portion 16. The thrust plate has a recess 30 in the face thereof adjoining the shaft in which recess is contained a hardened steel ball bearing 31 which makes contact with the end face 26 of the shaft.

The ball is caused to bear against the shaft by resilient means in the form of a dished compression washer, or Belleville washer, 32 contained between the thrust plate 28 (which has shoulders 33 to locate it in the hole in the washer) and an end cover 34 secured to the body by screws 35.

The thrust plate 28 is limited in travel along the passage towards the portion 16 by a shoulder 36 on the body against which the plate abuts under the action of the compression washer 32. The ball 31 is a press fit in the recess 30 and the shaft 18 is free to move along the passage, being drawn to a position engaging the ball by magnetic attraction between the rotor magnet and the iron yoke of the stator. The rotor shaft is prevented from being pulled out of the passage by relying on engagement between the impeller and the tapering nose of the missile.

When the missile is fired the impeller rotor and shaft are set back, the force being transmitted by the ball to the thrust plate which causes flattening of the compression washer. Set-back force is usually large and short lived such that there is no gain in absorbing all the force in the compression washer. The compression washer flattens to such an extent that the rotor 22 bears against the annular yoke member 25, the washer resilience causing the contact to be made gently without damage to the alloy material of the rotor. After launch when the pressure on the rotor is due only to the pressure of air against the impeller the compression washer absorbs variations in axial thrust while maintaining longitudinal clearance between the rotor and stator. The use of a ball bearing 31 against a substantially flat end of the shaft means that the bearing makes only point contact and the frictional loss is kept small even under considerable pressure between the shaft and the ball which may cause a slight dishing of the face at set-back.

The generator is arranged to satisfy the power requirements of the missile while rotating a speed of up to 60,000 r.p.m. for less than two minutes of flight.

The construction is chosen to satisfy the operating requirements as outlined above but also to simplify the construction procedure and lessen the cost.

The simplicity of construction may be appreciated from the following assembly procedure. Firstly the rotor assembly is made by sliding the magnet 22 and impeller 19 onto the shaft 18 and fixing thereto. The stator is formed by winding the coil 14 in iron yoke 13 and encapsulating them in the body 12 in a transfer or injection moulding operation. The needle roller bearings 17, thrust plate 28 (with ball 31) compression washer 32 are inserted into their respective sections of the passage 15 and the end cover 34 screwed to the body. The shaft of the rotor assembly is inserted in the passage 15 to be retained by magnetic attraction between the permanent magnet 22 and the iron yoke.

It will be seen that the assembly procedure is simple and requires manipulation of relatively few components, making it suitable for high volume production by automated machinery or unskilled labour.

The main feature responsible for enabling such uncritical assembly while satisfying the design tolerances for correct operation is the accurate moulding within the body of the passage 15 with its enlarged portions so that the bearing components can all be carried and the rotor assembly supported for correct clearance of the stator. In the above described embodiment the body 12 is moulded around the stator in a transfer or injection moulding operation. This requires an expensive moulding tool but is relatively cheap to manufacture thereafter. It will be appreciated that the body may be formed in other ways, for example machining from a solid block of suitable plastics material cast around the stator or by fixing together a number of annular members each having a central aperture corresponding to one of the diameters of the different portions of the axial passage 15.

Variations are possible also in the other component parts of the turbine generator. The impeller 19 is described as being formed out of plastics material. Clearly it could be formed from a metal, preferably a light alloy. Similarly the thrust plate 28 described as being formed of such a light alloy could be made of a suitable plastics material.

The resilient means preferably takes the form of a compression washer as a means of providing strong resilience for a very small axial length. However, where space permits other forms of resilient means, such as a coil spring may be employed.

The magnet may be attached to the shaft 18 as an unmagnetised component and magnetized in situ at the completion of assembly of the generator. The material described is an example of an alloy having isotropic magnetic properties enabling a plurality of poles to be formed around its periphery. If desired any other isotropic material having suitable magnetic properties may be employed.

CLAIMS

1. A generator for a missile comprising a stator body supporting an electromagnetic stator coil and a ferromagnetic yoke contained in a stator body, said coil being wound around an axial passage through the body, a shaft of non-magnetic material extending along the passage and journalled for part of its length within the passage by journal bearing means supporting the shaft against radial movement relative to the body, said shaft carrying a permanent magnet rotor and having one end adapted to carry an impeller arranged to face the direction of travel of a missile to which the generator is fitted to receive ram air directed axially of the shaft and to redirect it to cause rotation of the shaft and having the other end formed substantially flat in a plane perpendicular to the longitudinal axis of the shaft, and an axial thrust bearing comprising a thrust plate, adapted to close the portion of the axial passage containing the journal bearing and the shaft, and a ball bearing supported in a recess in the plate so as to bear against said other end of the shaft by resilient means held between the thrust plate and an end cover attached to the stator body, said resilient means reacting deformably to axial forces on the shaft transmitted by the ball and thrust plate.

2. A generator as claimed in Claim 1 in which the journal bearing comprises a plurality of caged needle rollers contained within a portion of the passage.

3. A generator as claimed in Claim 2 in which the bearing length is at least twice the diameter of the shaft.

4. A generator as claimed in any one of Claims 1 to 3 in which the thrust plate is formed of metal.

5. A generator as claimed in Claim 4 in which the metal is an aluminium alloy.

6. A generator as claimed in any one of Claims 1 to 5 in which the ball is of hardened steel.

7. A generator as claimed in any one of the preceding claims in which the resilient means comprises a compression washer.

8. A generator as claimed in any one of the preceding claims in which the stator body comprises a moulding of thermoplastic resin into which the stator components of the generator are moulded.

9. A generator as claimed in any one of the preceding claims in which the shaft has a narrowed portion on which the permanent magnet rotor and impeller are carried adjacent to each other, said rotor abutting a shoulder with the remainder of the shaft.

10. A generator as claimed in any one of the preceding claims in which the permanent magnet rotor comprises an annular ring of isotropic magnetic material having a plurality of opposite poles arranged around its peripheral surface.

11. A generator as claimed in Claim 10 in which the isotropic material is aluminium-nickel-iron alloy.

12. A generator for a missile substantially as herein described with reference to, and as shown by, the accompanying drawings.

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